NS102 Lecture 8 April 26, 2005

Opening: *Dark Center of the Universe,* Modest Mouse
Closing: *Homesick at Space Camp,* Fallout Boy

GnatSigh News

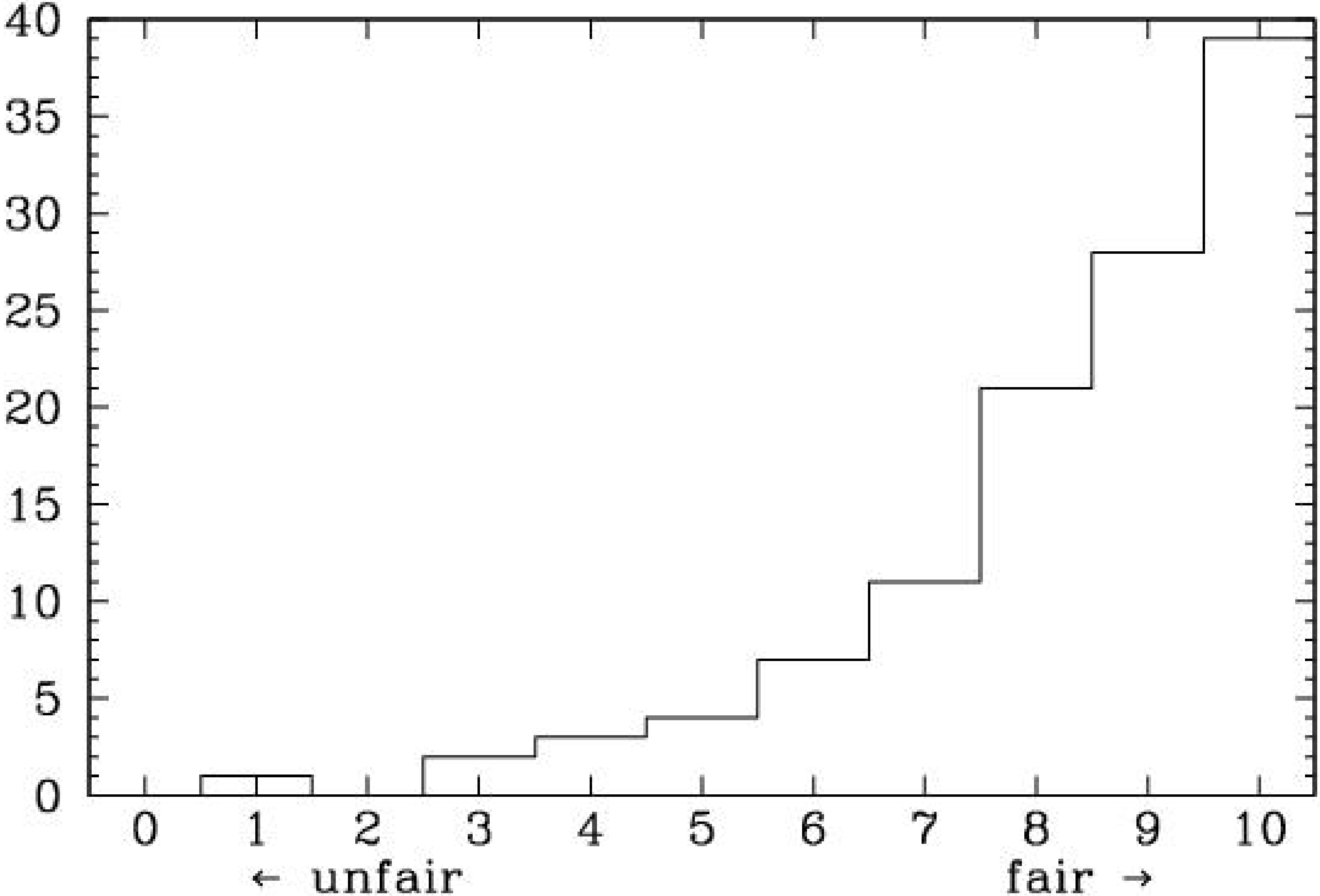
(all the news that fits)

- Website http://home.fnal.gov/~rocky/NS102/
- Need violinist volunteer
- Review logarithms
- Review basic trigonometry (definition of sine, tangent, etc.)
- Exam #1 be returned on Thursday (exit polling good)

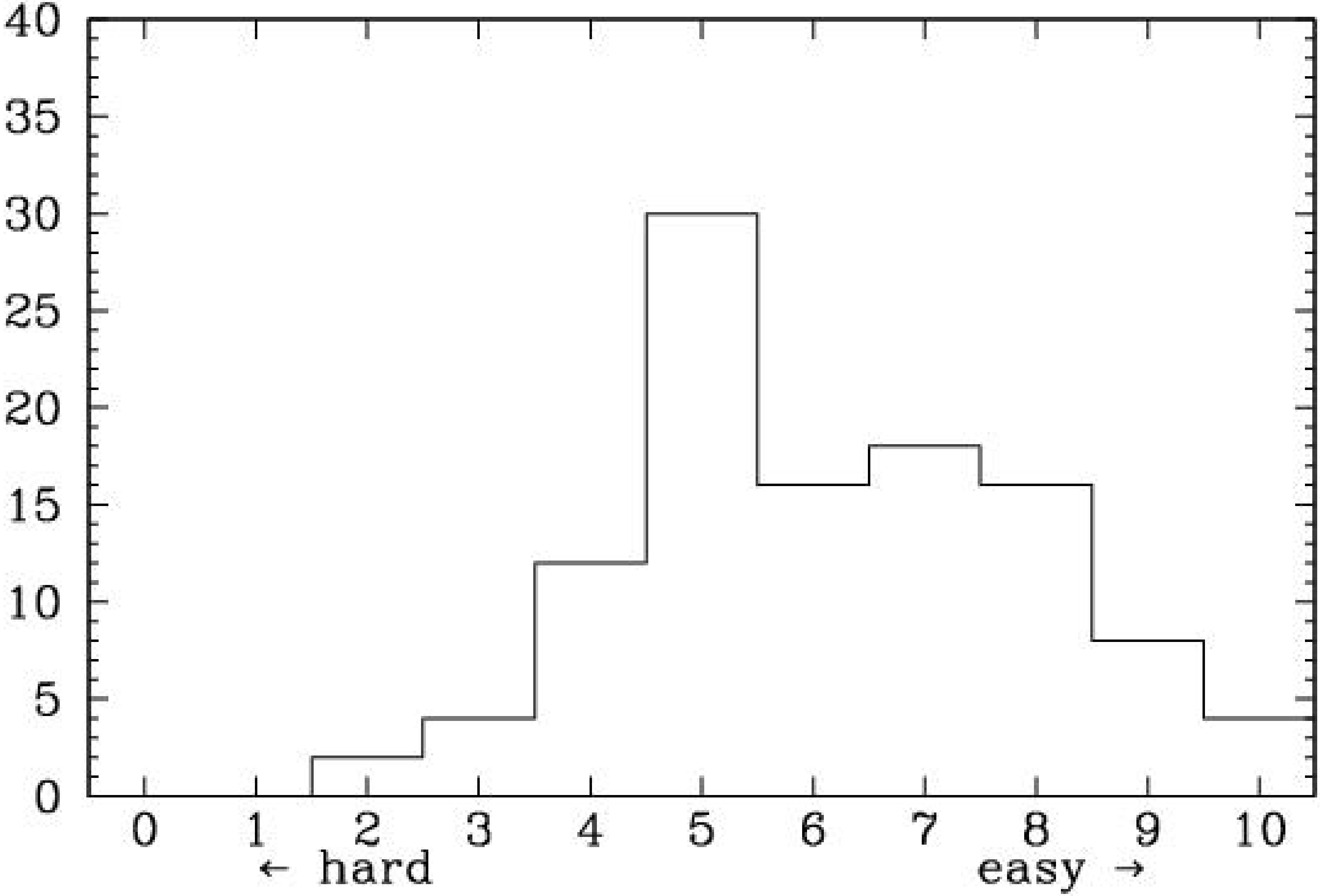
Lab this week: Temperature of the Universe

Lab next week: Geometry of the Universe

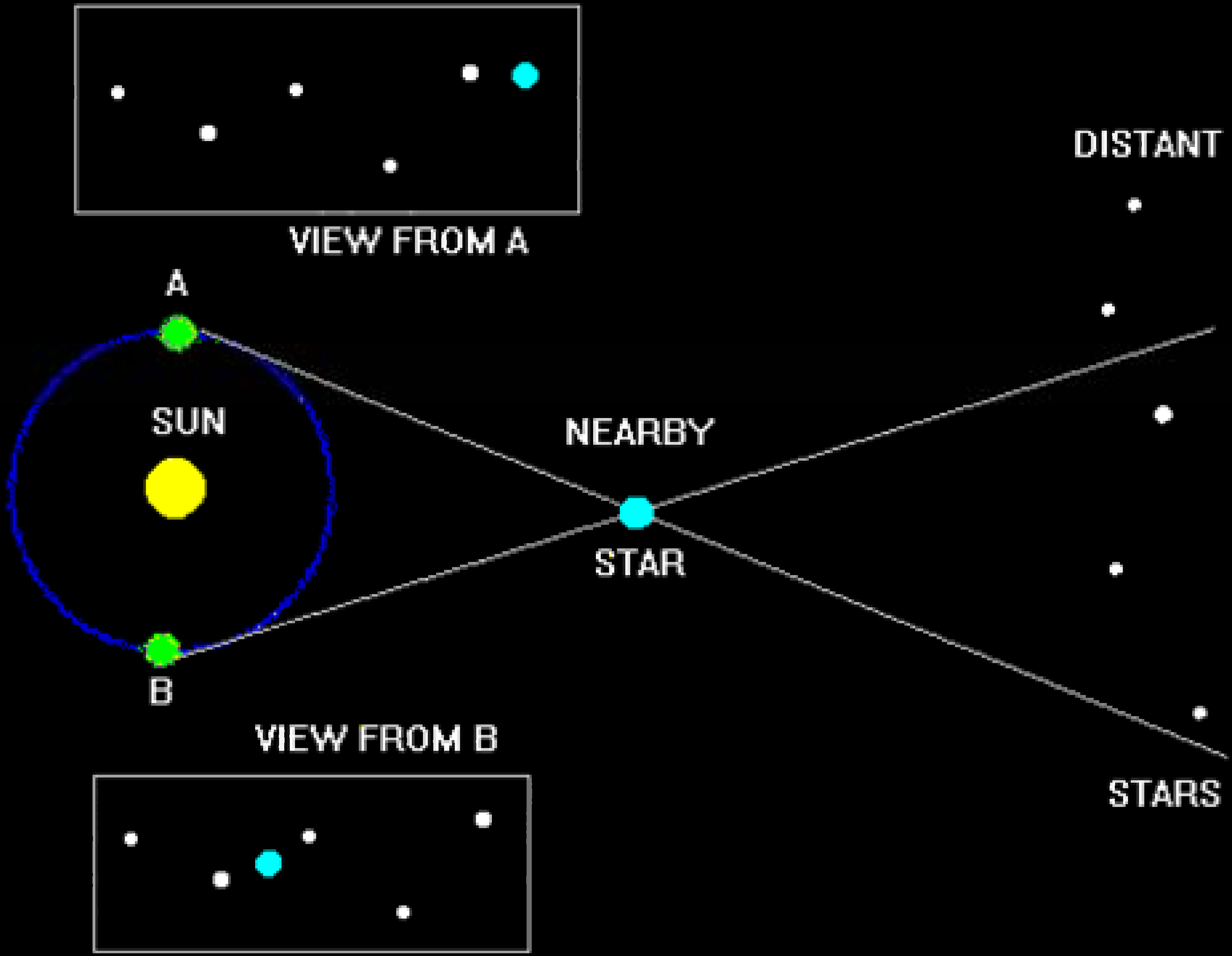
NS102 Spring 2005 Exam #1



NS102 Spring 2005 Exam #1



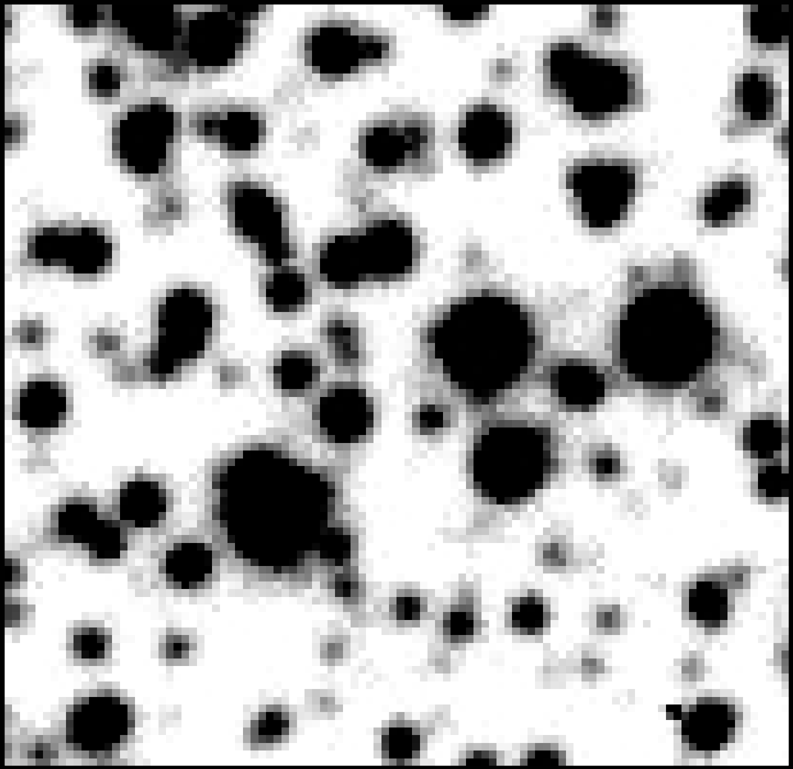
1 2 3 4 5 6 7


VIEW FROM A
DISTANT
A
SUN
NEARBY
STAR
B
VIEW FROM B
STARS

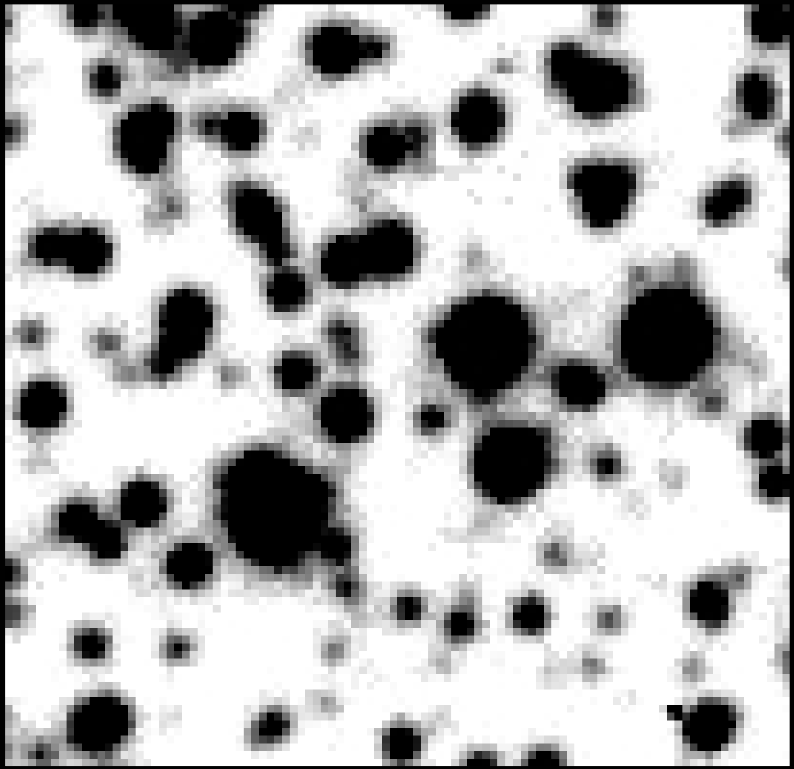
January

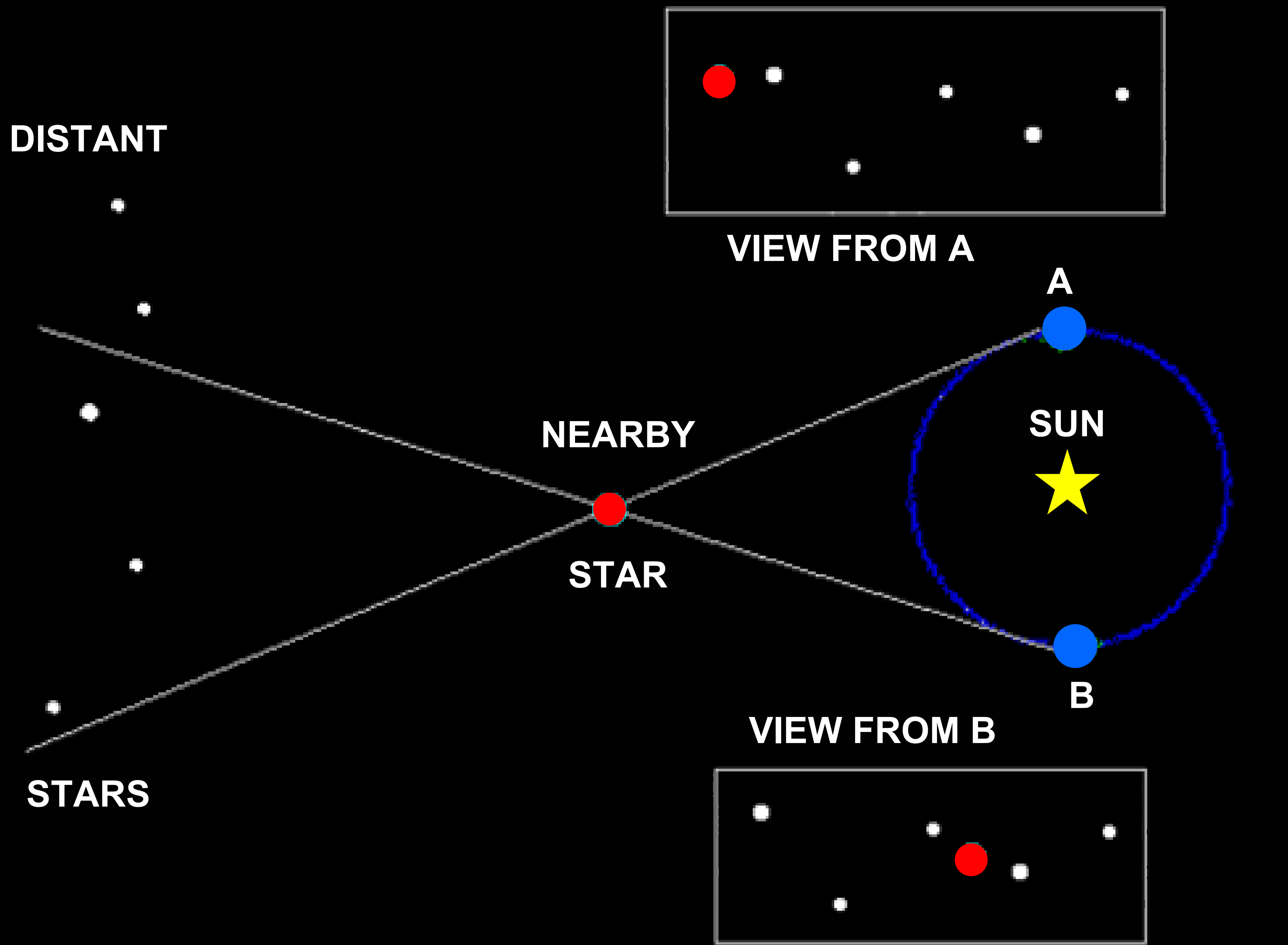
June

January

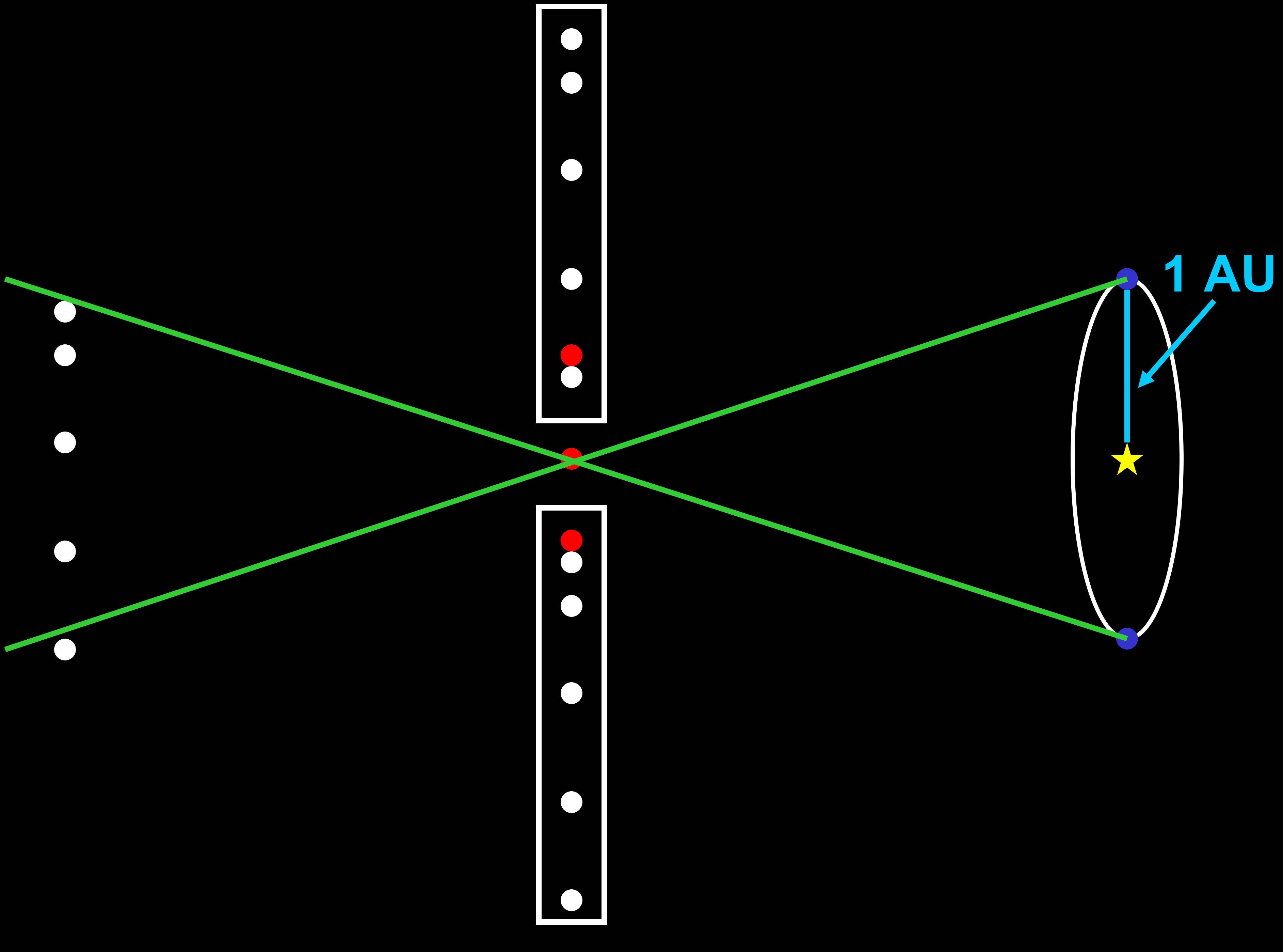


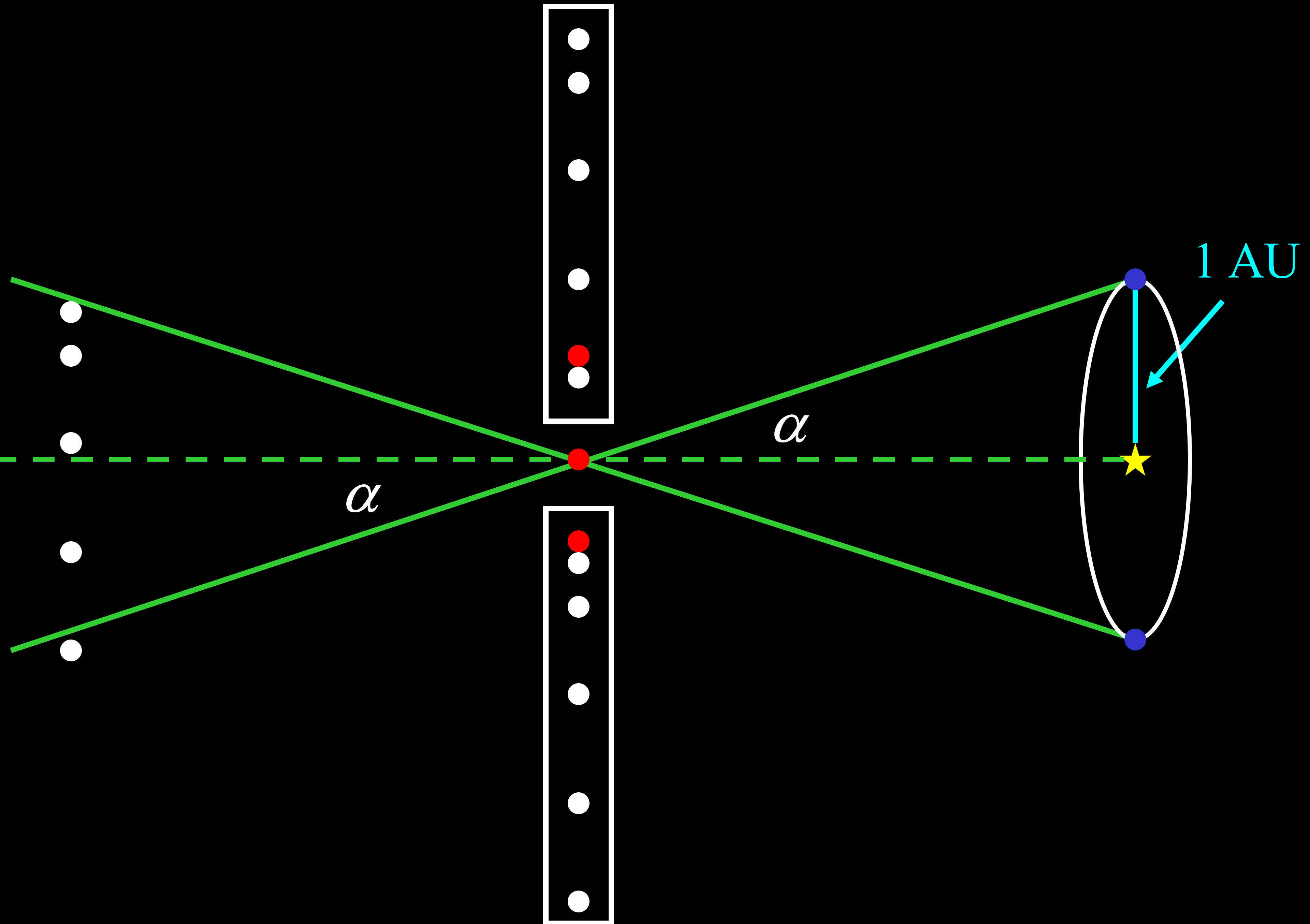
June



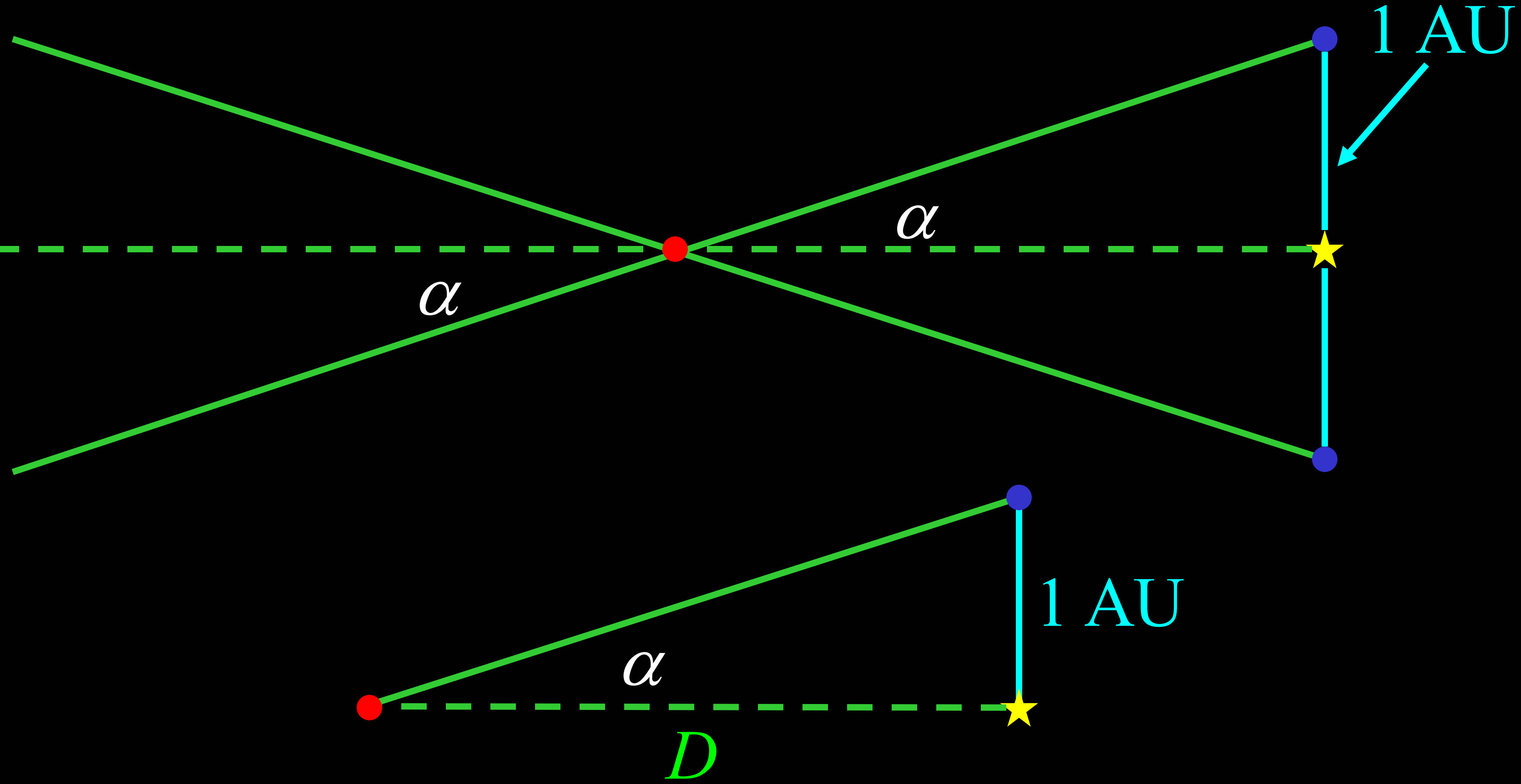


DISTANT
STARS
NEARBY
STAR
SUN
A
B
VIEW FROM A
VIEW FROM B

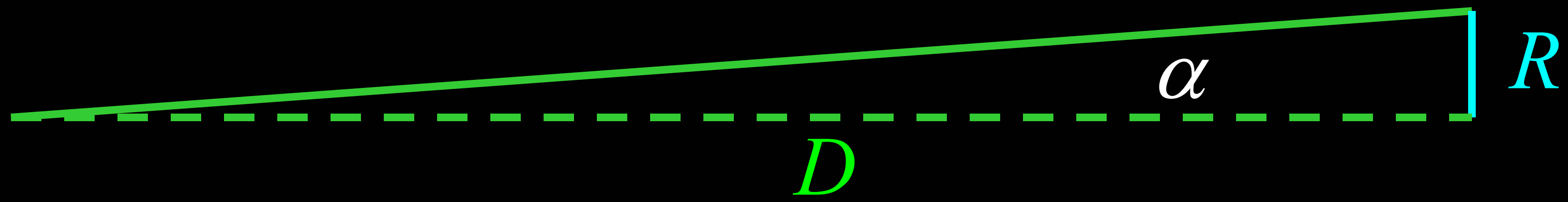

1 AU



1 AU
α
α



$$\tan\alpha = \frac{1\ \mathrm{AU}}{D}$$



$$\tan\alpha = \frac{R}{D}$$

law of skinny triangles:

$$\tan\alpha = \sin\alpha = \alpha \quad \text{(in radians)}$$

$$\alpha \quad \text{(in radians)} = \frac{R}{D}$$

What's a radian?

$$2\pi \text{ radians} = 360 \text{ degrees}$$

$$1 \text{ radian} = \frac{360}{2\pi} \text{ degrees} \sim 60 \text{ degrees}$$

$$0.01 \cancel{\text{radians}} \times \frac{60 \text{ degrees}}{1 \cancel{\text{radian}}} = 0.6 \text{ degrees}$$

$$3 \cancel{\text{degrees}} \times \frac{1 \text{ radian}}{60 \cancel{\text{degrees}}} = 0.05 \text{ radians}$$

The skinny on traingles

α (degrees)	α(radians) = α (degrees) $\times \dfrac{2\pi}{360^\circ}$	$\tan\alpha = \alpha + \dfrac{\alpha^3}{3!} + \cdots$	$\sin\alpha = \alpha - \dfrac{\alpha^3}{3!} + \cdots$
3º	0.05236	0.05241	0.05234
10º	0.17453	0.17633	0.17365
30º	0.52360	0.57735	0.50000
100º	1.74533	–5.67128	0.98481

F 70

B C 60

P T E O 50

B Z F E D 40

O F C L T B 30

T E P O L F D Z 20

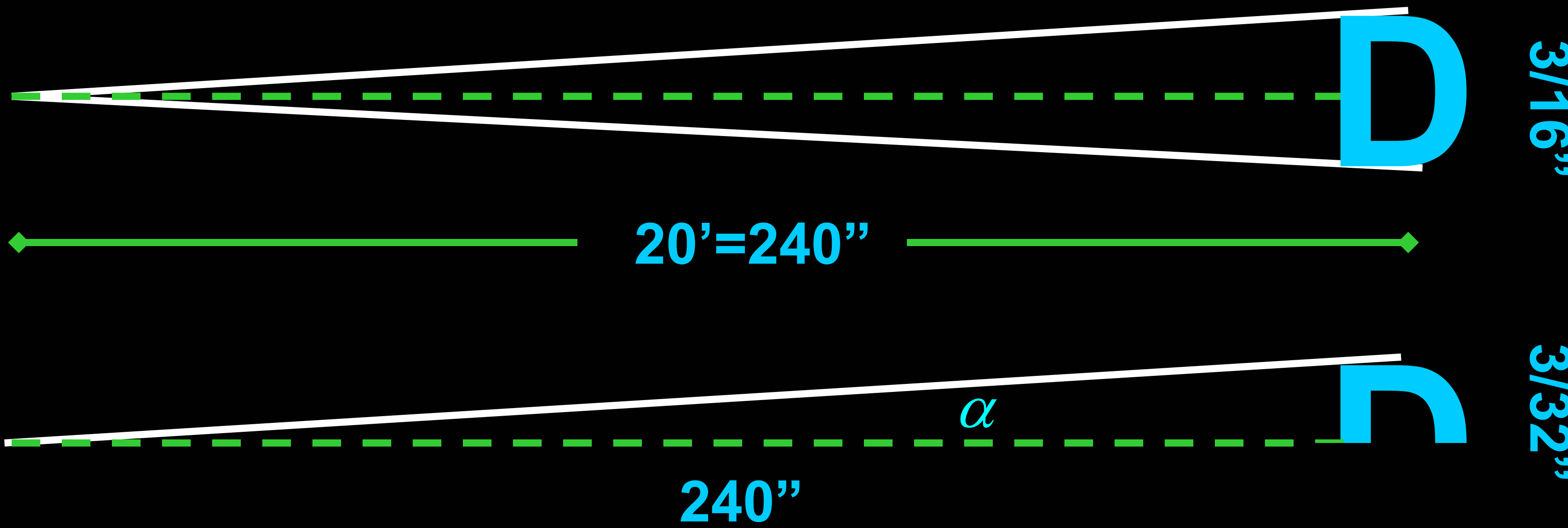
L P C T Z D B F E O 15

Z O E C F L D P B T 10

E T O L E B Z E F D C 7

B O F C P T E B L F B E Z C O P E 4

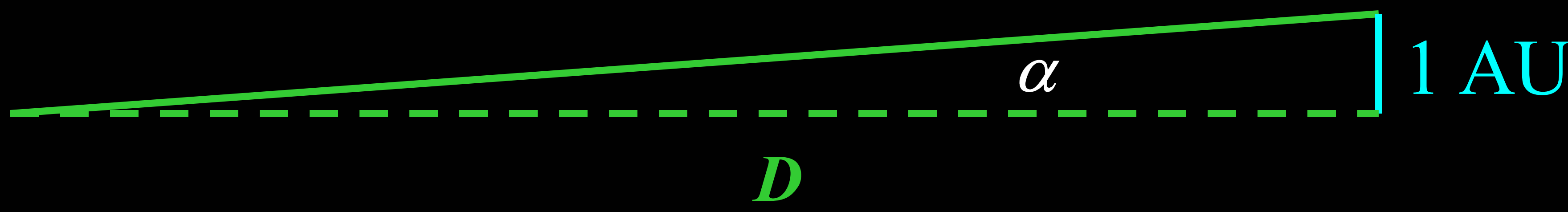
How good are your eyes?



$$\alpha = \frac{3}{32}\frac{1}{240} = 4\times 10^{-4}\ \cancel{\text{radians}} \times \frac{360\text{ degrees}}{2\pi\ \cancel{\text{radians}}} = 0.02^{\circ}$$

$$\alpha = 0.02^{\circ} \times \frac{60\text{ minutes}}{1\text{ degree}} = 1'$$

$$\text{D} = 2'$$

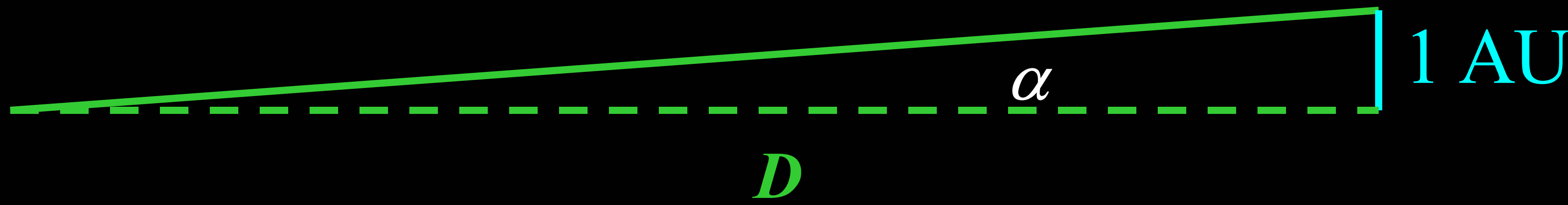


$$\alpha = \frac{1\ \text{AU}}{D}\ \cancel{\text{radians}} \times \frac{60\ \text{degrees}}{\cancel{\text{radian}}}$$

$$\alpha = \frac{60\ \text{AU}}{D}\ \cancel{\text{degrees}} \times \frac{60\ \text{minutes}}{1\ \cancel{\text{degree}}}$$

$$\alpha = \frac{3600\ \text{AU}}{D}\ \cancel{\text{minutes}} \times \frac{60\ \text{seconds}}{1\ \cancel{\text{minute}}}$$

$$\alpha = \frac{206{,}264.8\ \text{AU}}{D}\ \text{seconds}$$



$$\alpha = \frac{1\ \mathrm{AU}}{D}\ \text{radians}$$

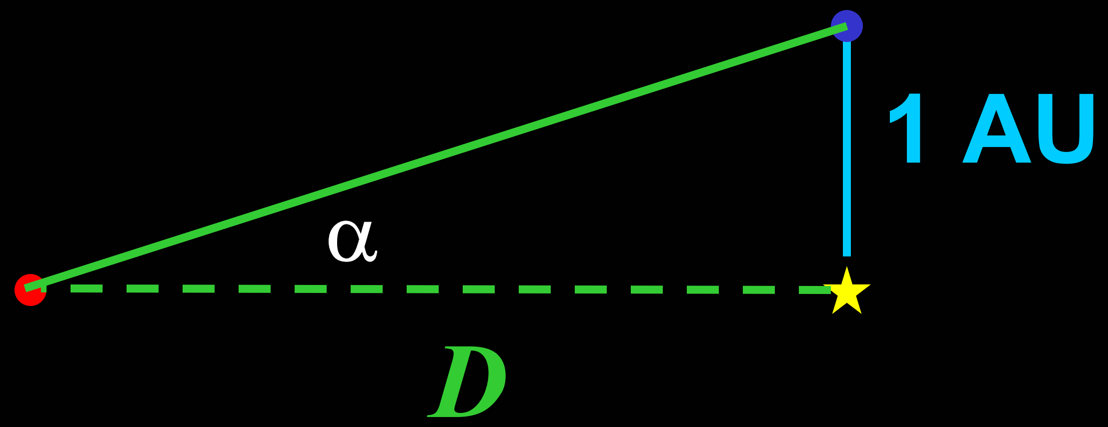
$$\alpha = \frac{206{,}264.8\ \mathrm{AU}}{D}\ \text{seconds}$$

1 pc = 206,264.8 AU = 3.26 light years
= 10^{13} (10,000,000,000,000) miles

$$\alpha = \frac{\mathrm{pc}}{D}\ \text{seconds} \qquad D = \frac{\text{second}}{\alpha}\ \mathrm{pc}$$

$$\frac{\text{D}}{200{,}000 \text{ AU}} = \frac{\text{seconds}}{\text{parallax}}$$

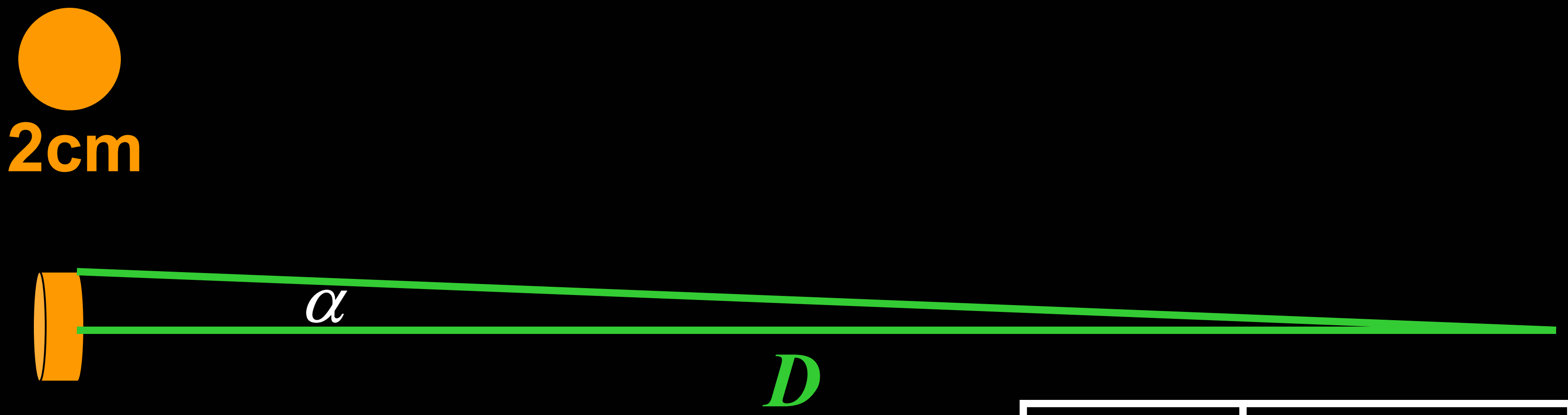
$$\frac{\text{D}}{\text{pc}} = \frac{\text{seconds}}{\text{parallax}}$$



$$\frac{D}{\text{pc}} = \frac{\text{seconds}}{\text{parallax}}$$

star	parallax (”)	distance (pc)
α Centauri	0.75	1.3
Barnard’s star	0.5	2.0
Sirius	0.4	2.5
Altair	0.2	5.0

Let’s think for a second of arc



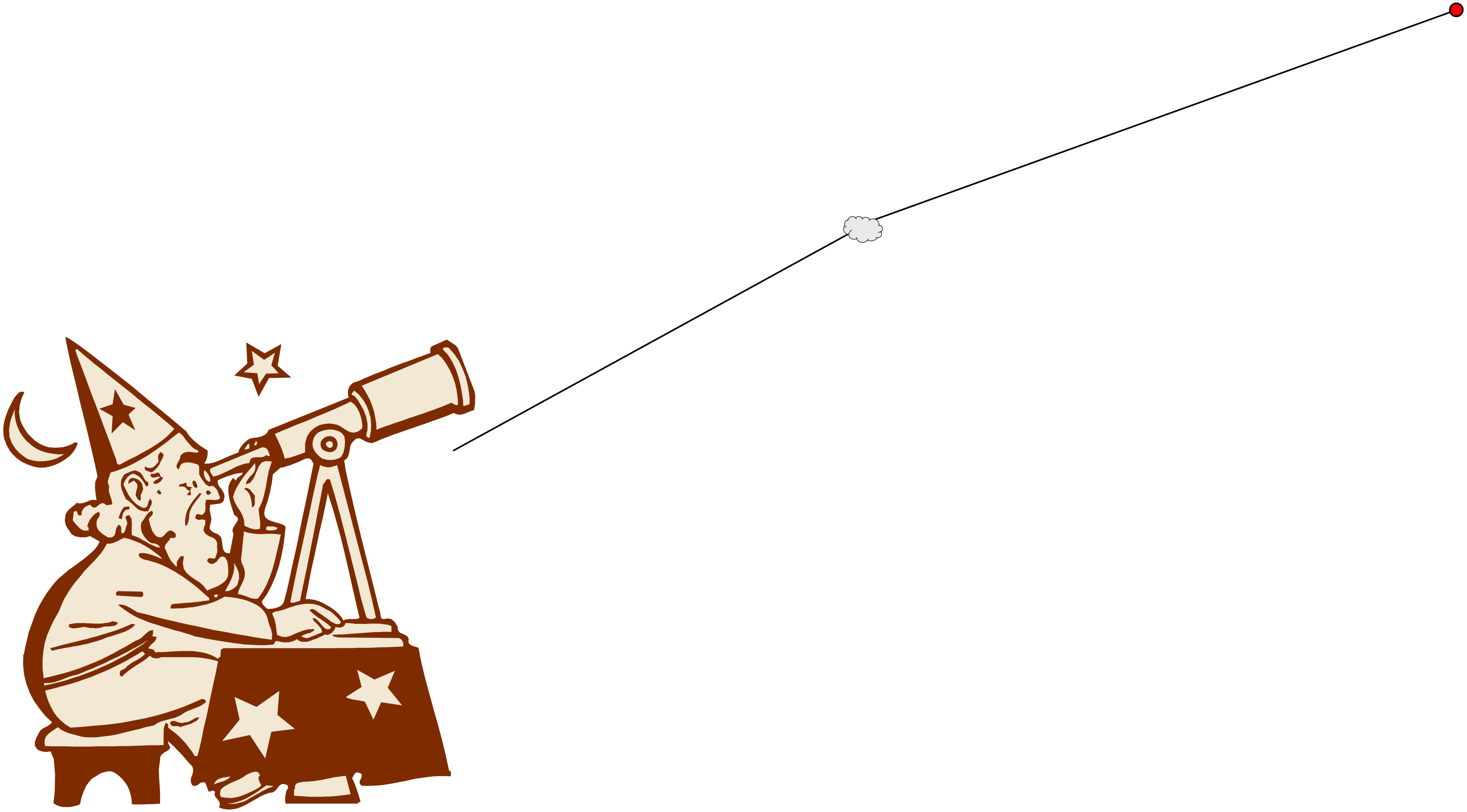
$$\alpha = \frac{1\ \text{cm}}{D}\ \text{radians}$$

$$\alpha = \frac{200{,}000\ \text{cm}}{D}\ \text{seconds}$$

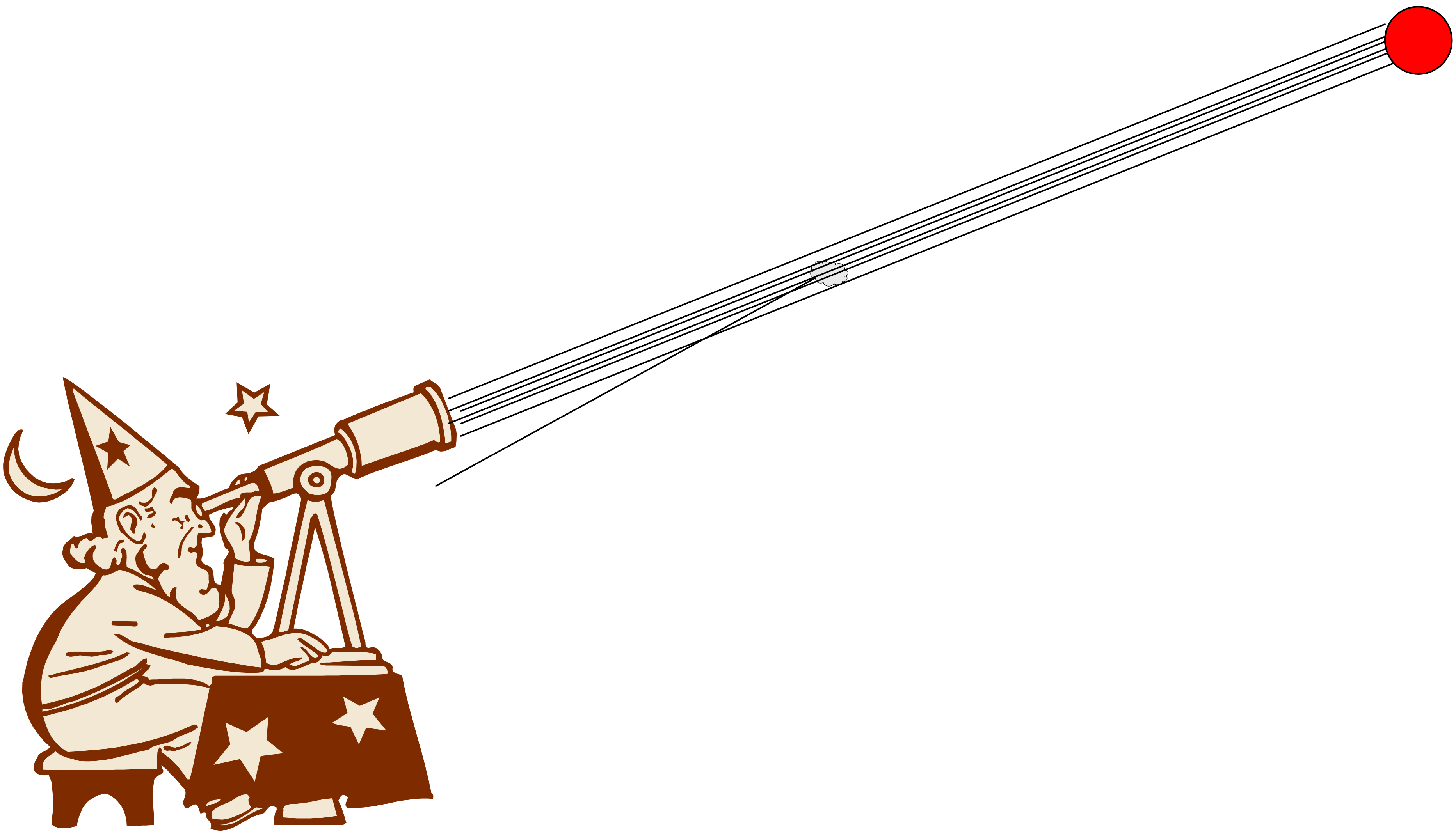
$$\alpha = \frac{2\ \text{km}}{D}\ \text{seconds}$$

α	D
4”	½ km
2”	1 km
1”	2 km
0.1”	20 km
0.01”	200 km
0”	infinity

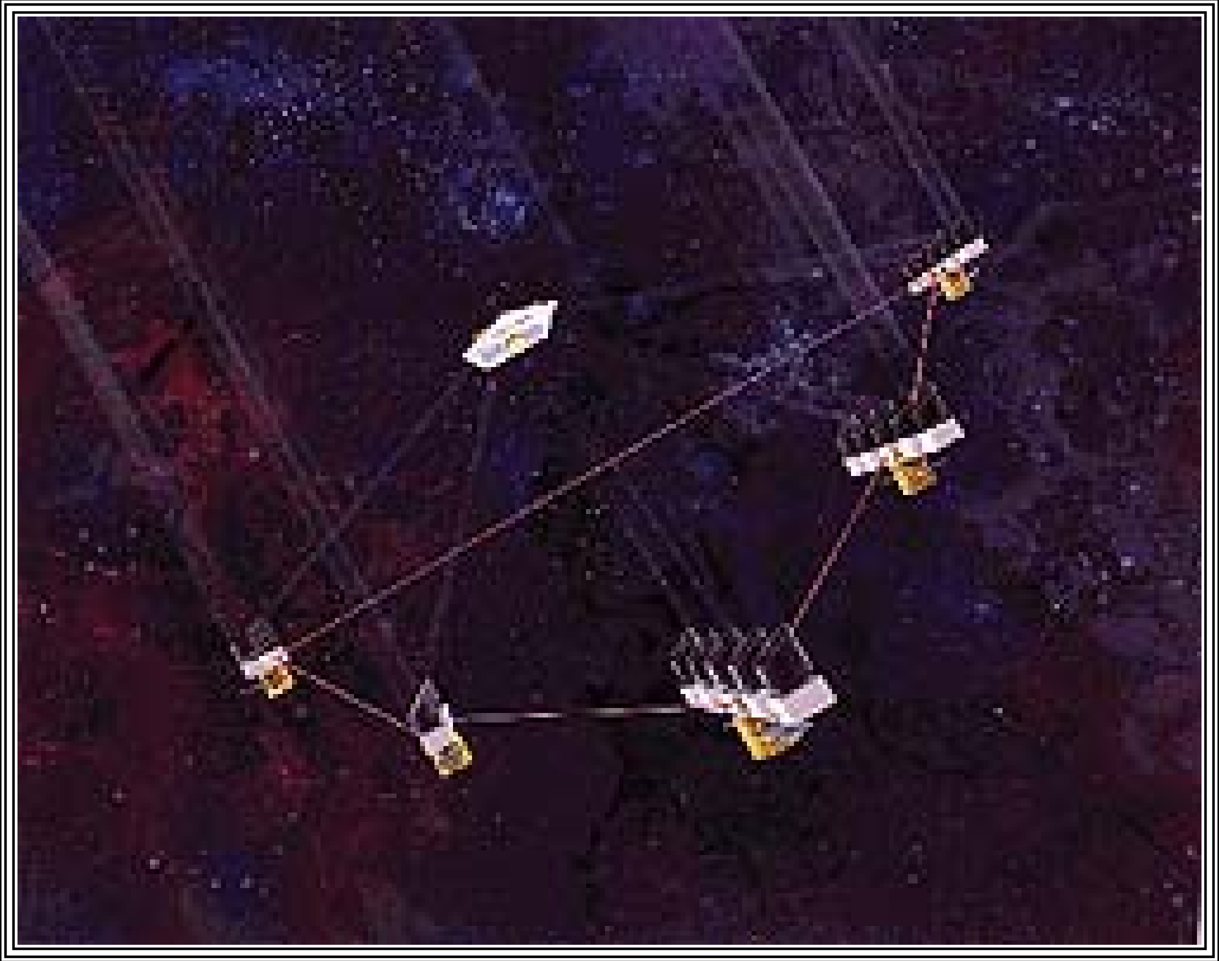
Twinkle, twinkle little star



Twinkle, twinkle little star



Hipparcos

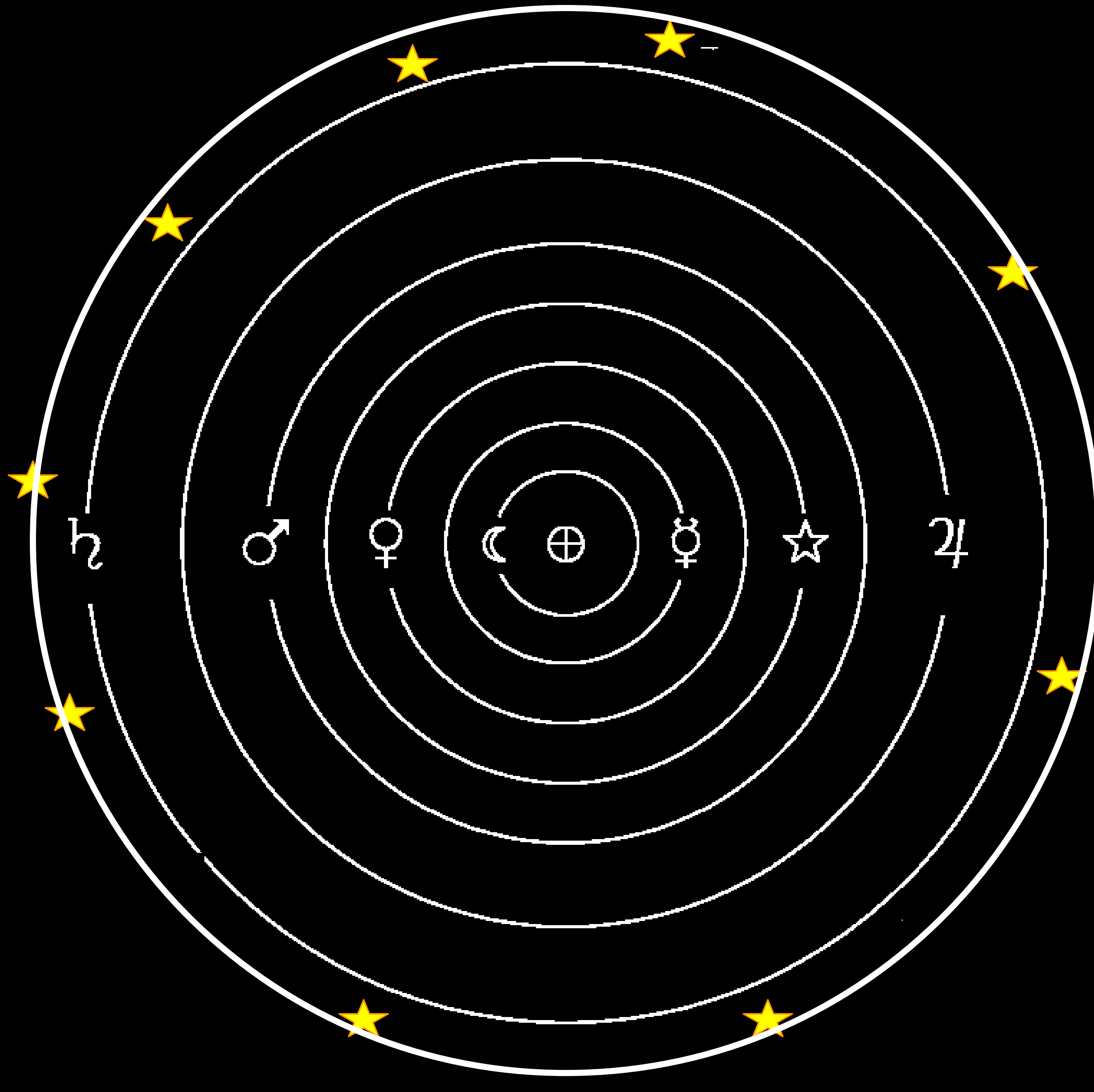


Planet Imager

Formation Flying

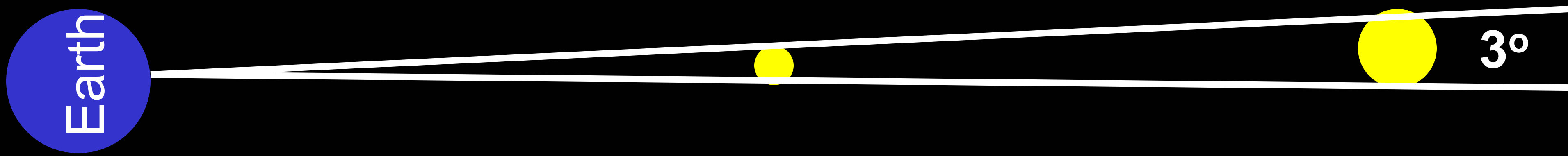
Launch: 2030

32 X 8 meter mirrors
Baseline = 6000 km

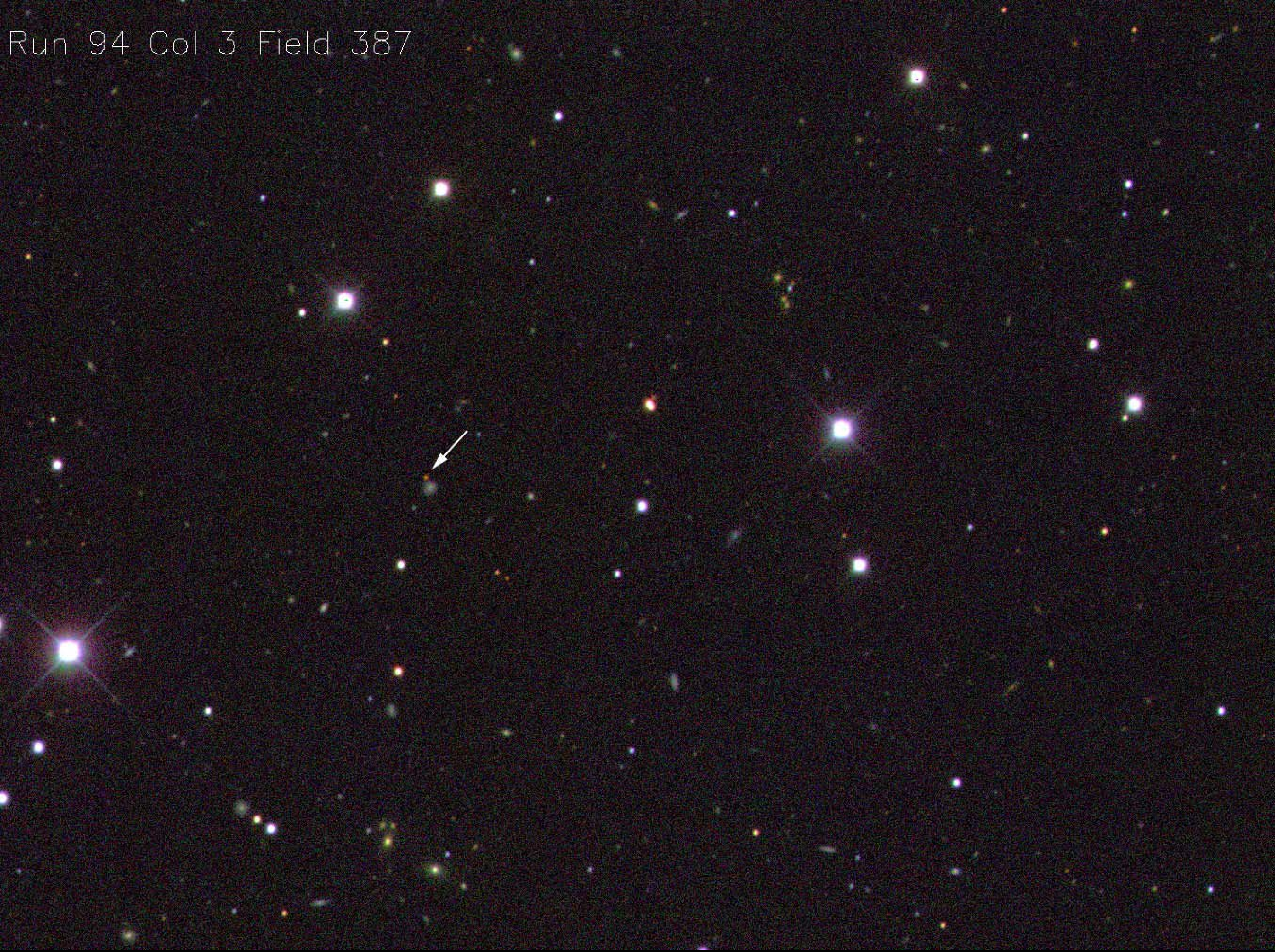


Planet	angular diameter (in minutes) Ptolemy	True
Mercury	2	0.01
Venus	3	0.5
Mars	1.5	0.15
Jupiter	2.5	0.4
Saturn	1.7	0.2
Bright stars	1.5	~0

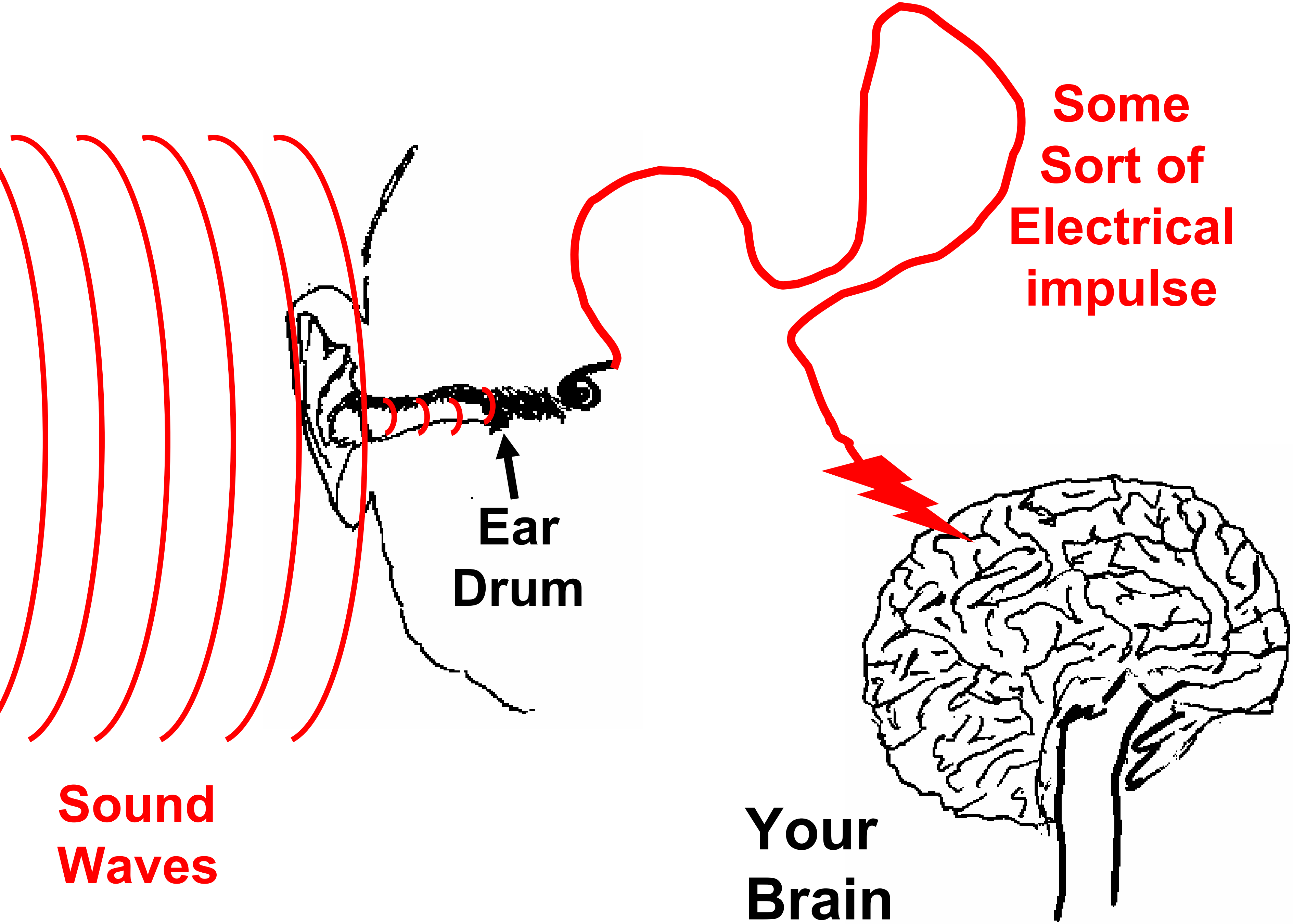
How far away are stars?   How big are stars?



Both objects have an angular diameter of 3°


Run 94 Col 3 Field 387

They have different apparent brightness
They have different colors
They move
They change in brightness


Some
Sort of
Electrical
impulse
Ear
Drum
Sound
Waves
Your
Brain

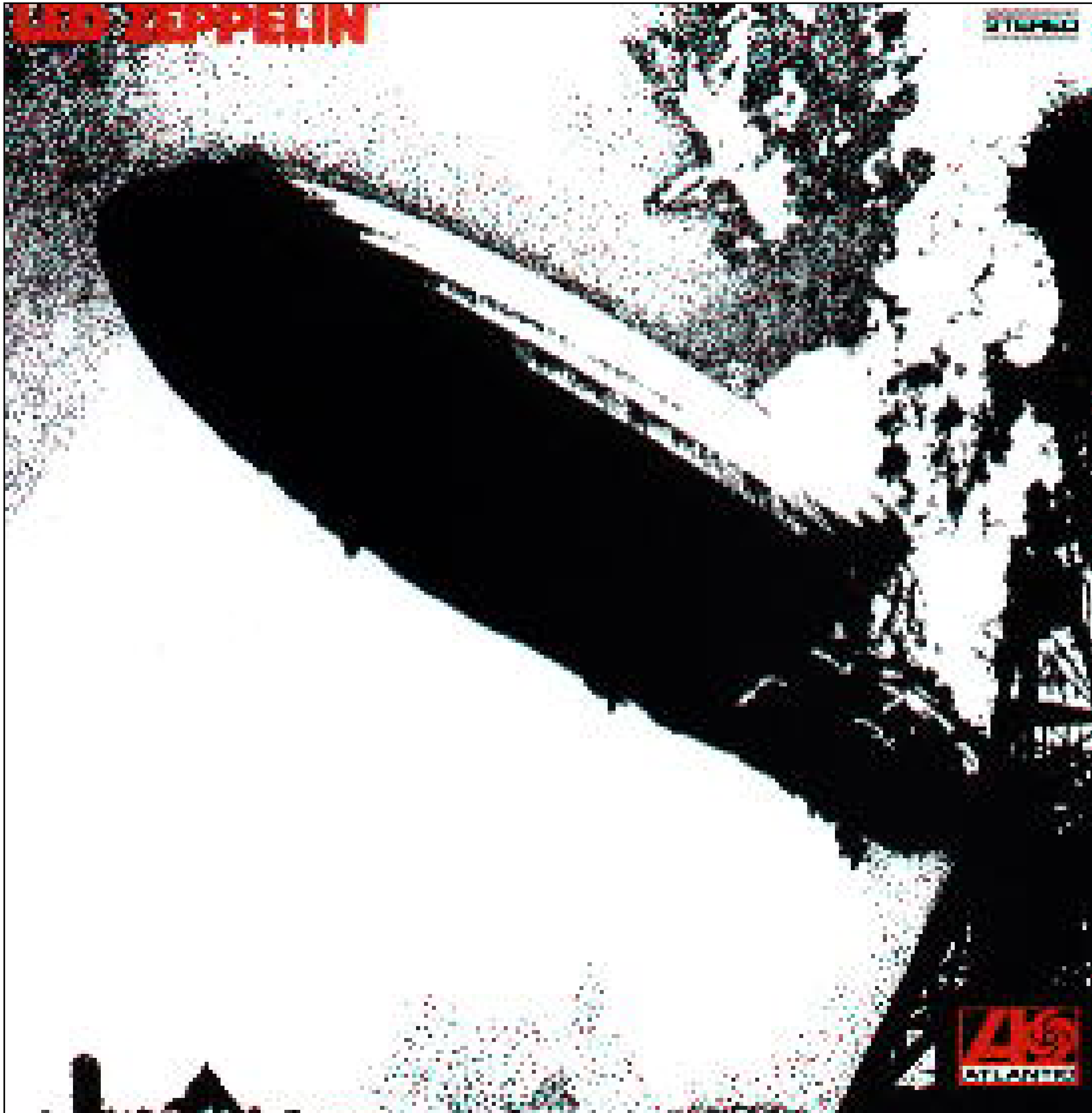
Loudness: Intensity: energy per second in ear

$I_{THRESHOLD}$ = energy per second in ear at threshold of hearing

I_{PAIN} = energy per second in ear at threshold of pain

$I_{PAIN} / I_{THRESHOLD}$ = ?

LED ZEPPELIN



Loudness: Intensity: energy per second in ear

$I_{THRESHOLD}$ = energy per second in ear at threshold of hearing

I_{PAIN} = energy per second in ear at threshold of pain

$I_{PAIN} / I_{THRESHOLD}$ = 10^{12} !!!

1 – 100 (10^2)

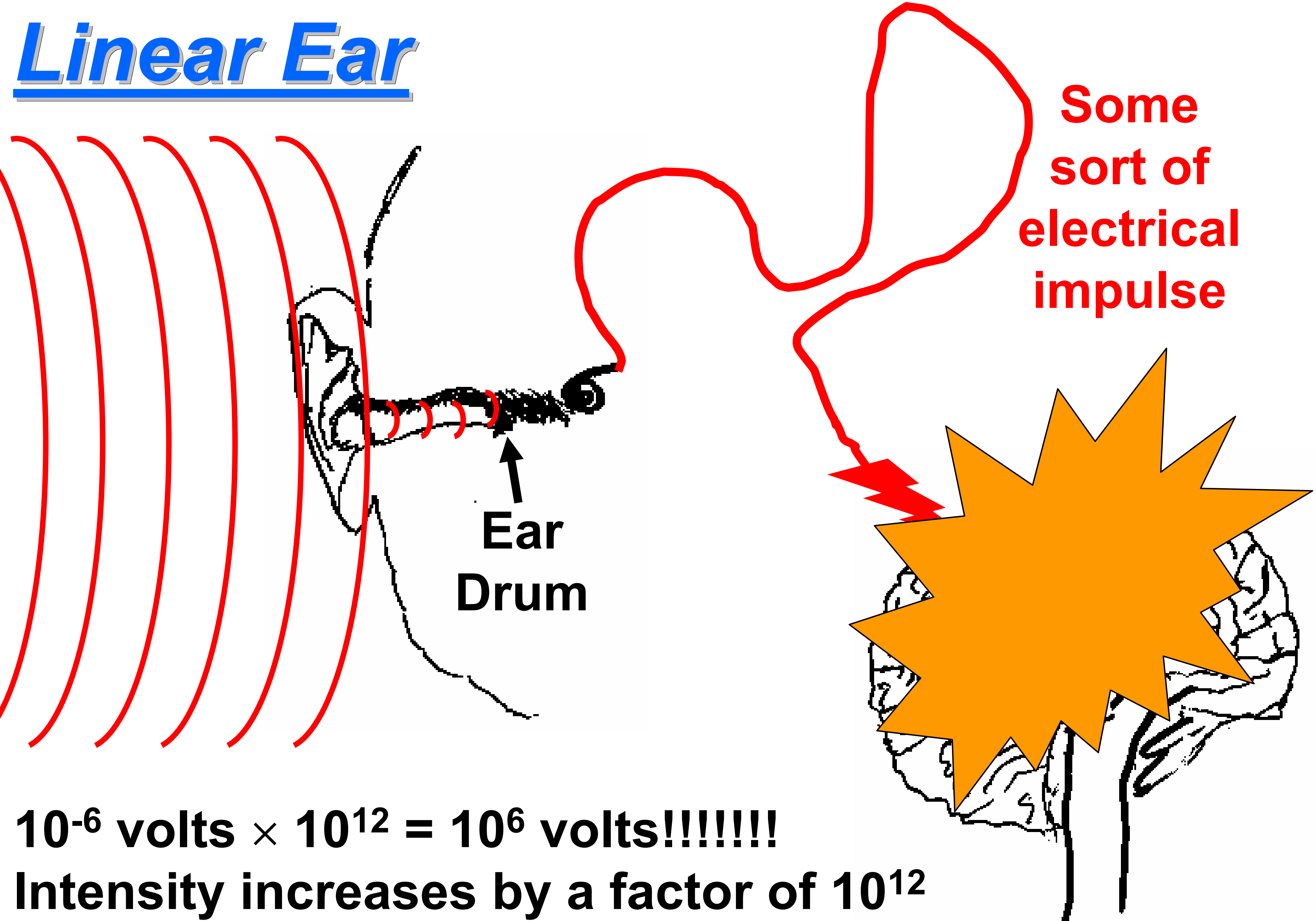
100 – 1,000 (10^3)

1,000 – 1,000,000 (10^6)

1,000,000 – 1,000,000,000 (10^9)

1,000,000,000 – 1,000,000,000,000 (10^{12})

Linear Ear



10^{-6} volts $\times$ 10^{12} = 10^{6} volts!!!!!!!

Intensity increases by a factor of 10^{12}

$\rightarrow$ electrical impulse increases by 10^{12}

Intensity: energy per time per area

$$I = \frac{\text{Energy}}{\text{Time Area}}$$

I_0 = threshold of hearing

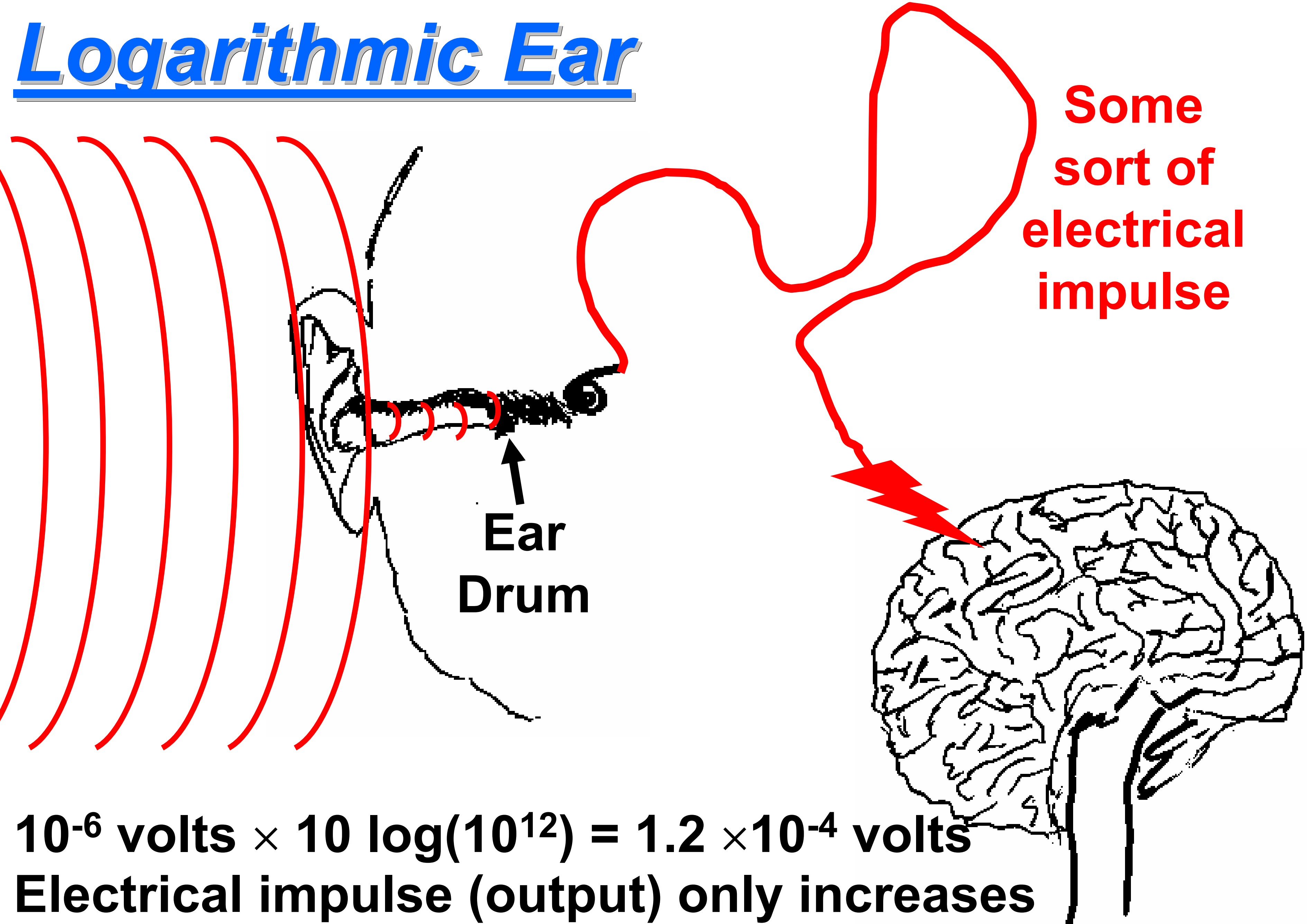
$$dB = 10 \log (I/ I_0)$$

$$I/ I_0 = 10^{12}$$

$$\log (10^{12}) = 12$$

$$dB = 10 \times 12 = 120$$

Logarithmic Ear



10^{-6} volts $\times$ 10 log(10^{12}) = 1.2 $\times 10^{-4}$ volts

Electrical impulse (output) only increases as the logarithm of the input

I_0 is intensity at threshold of hearing

I/I_0	$\log (I/ I_0)$	$dB = 10 \log (I/ I_0)$
10^{-2}	-2	-20
1	0	0
10^{2}	2	20
10^{6}	6	60
10^{12}	12	120
10^{20}	20	200